Silicon Carbide Multi-Chip Power Modules (MCPMs) for Plug-In Hybrid Electric Vehicles (PHEVs)

Summit Spotlight
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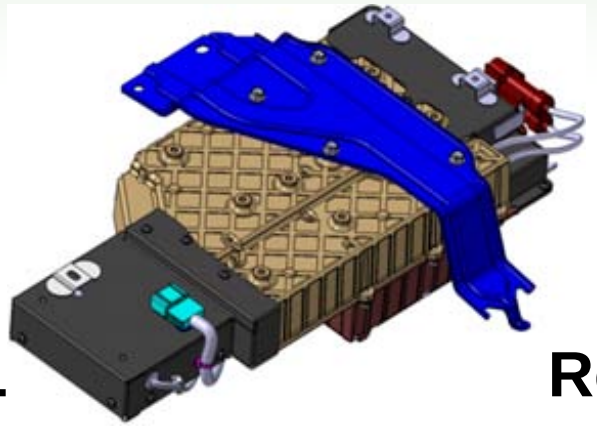
Program Manager: Dr. Ty McNutt
Principal Investigator: Dr. Alex Lostetter

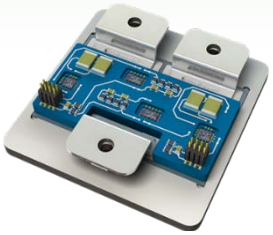
Arkansas Power Electronics International, Inc.
535 W Research Center Blvd. Suite 209
Fayetteville, AR 72701
Office: 479-443-5759
www.apei.net

Motivation for Highly-integrated, Silicon Carbide-Based PHEV Charger

2 kg, 2.75 L



10x Reduction



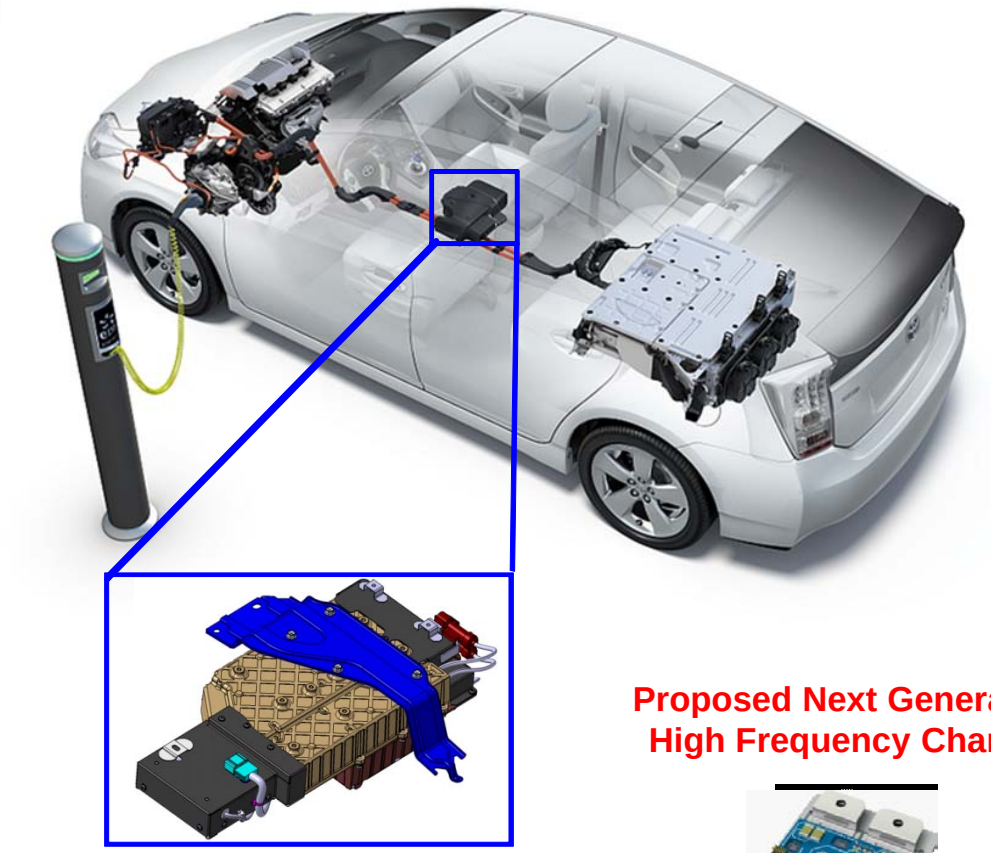
0.2 kg, 0.275 L

Specification	Today's Silicon Technology	Silicon Carbide (SiC) Technology
Semiconductor Temperature Limit	150 C	250 C
Heat Sinking	High volume & mass	Limited volume & mass or elimination
Switching Frequency	Low. Limits miniaturization	High. Enables miniaturization
Grid-tie Capability	No	Yes (Bi-directional)

ADEPT Program - Development of a 5 kW Plug-In Charger for Toyota Prius

Goals

- Develop a Mult-Chip Power Module (MCPM) for >500 kHz Operation
- Develop high-speed 1200V, 20A SiC MOSFET with isolated, integrated SiC gate drive
- Topology with >94% efficiency, > 5kW/kg, > 100W/in3
- Small, lightweight, few materials, low cost
- Integrate into Prius vehicle and demonstrate operation



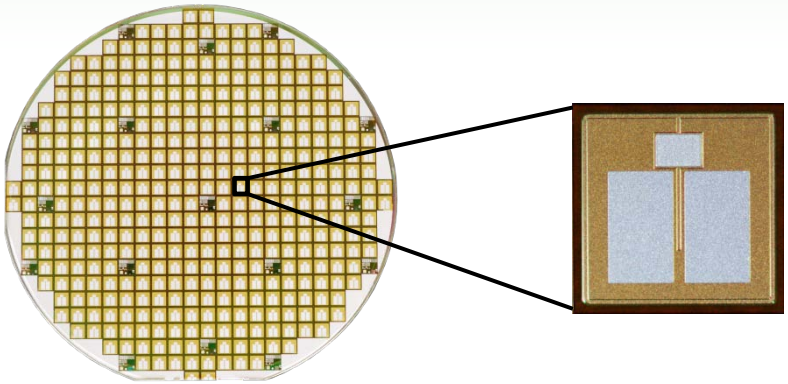
Present Plug-in Charger

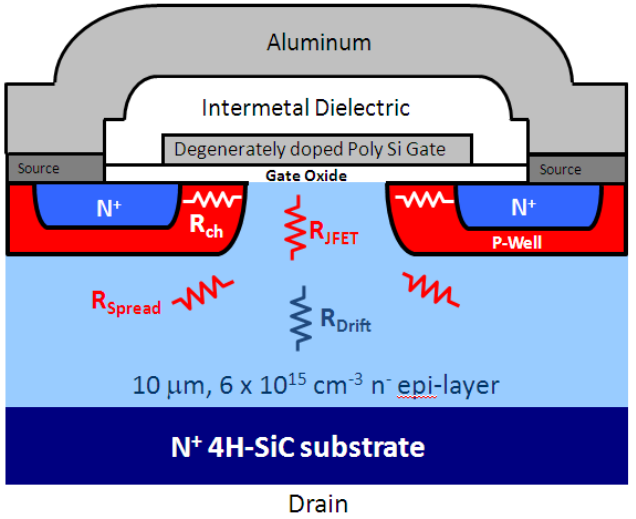
Proposed Next Generation High Frequency Charger

SiC Enables 10 x Size/Cost Reduction

SiC Power MOSFET Must Be Optimized For High Frequency

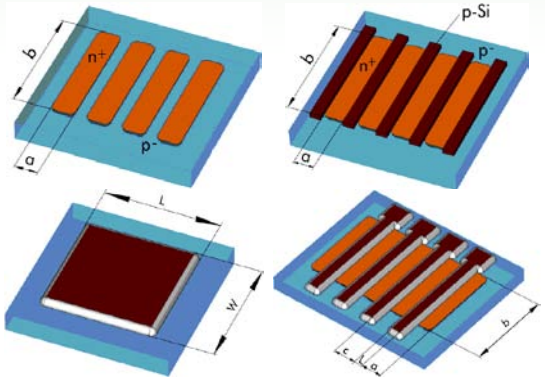
- **<u>Program Challenge</u>**: Power MOSFET process not optimized for Integrated Circuit (IC) implementation
  - Limited options in design layers
- Power MOSFET On-Resistance Targets 33% Reduction
  - MOS channel resistance, Spreading resistance are dominant components





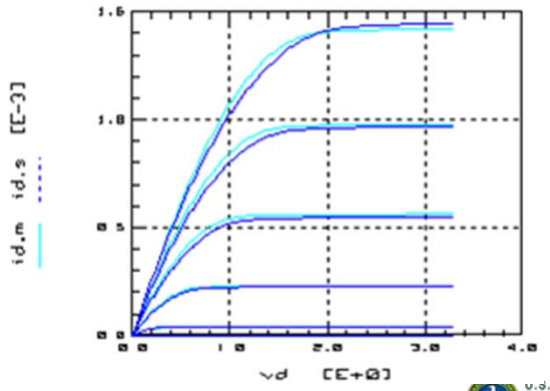
First-of-Kind Integrated, Isolated Gate Drive/Power MOSFET for Ultra-High Switching Frequencies

- Integrated Gate Drive - Compatible with SiC Power MOSFET Process
  - Gate driver design will be implemented using only nMOS
- An accurate CAD environment must be developed for IC integration

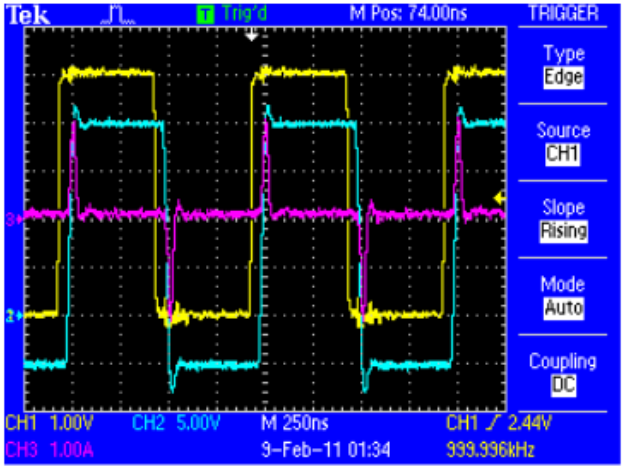


Process Characterization

Accurate Models

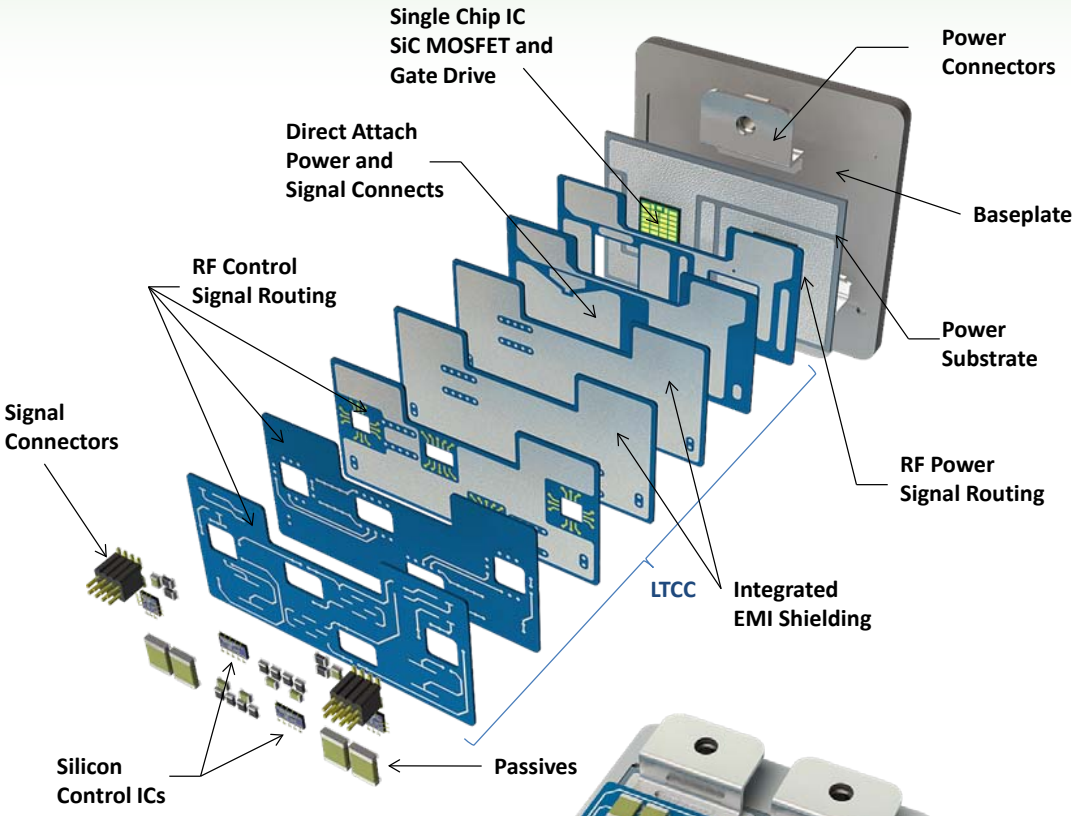


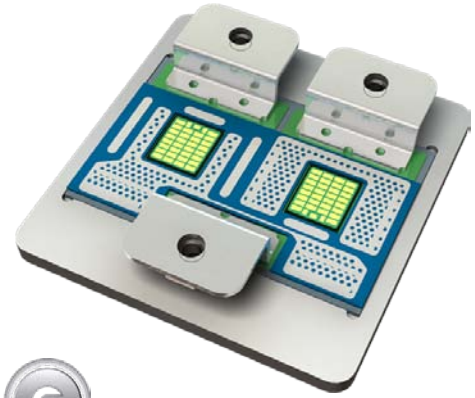
Maximum Performance



PHEV Charger Development Uses Silicon Carbide Components & Proven MCPM Technology

- Key Attributes
  - SiC power MOSFETs
  - SiC gate drive ICs
  - Si high temperature controls
  - High temperature packaging (>200 °C)
  - High frequency & low parasitics
  - High temperature die attach
  - High temperature passives





Low-Cost, Highly-Integrated SiC Module Will Be Demonstrated in a Toyota PHEV

- A Toyota Plug-In HEV Prius is being delivered for insertion of SiC-based 5 kW Charger unit
  - 10x smaller
  - 10x lighter
  - Lower cost